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Sleep and Chronotype in Adults with Persistent Tic Disorders

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Abstract

Objective: This study examined sleep disorders and sleep medication use rates, nighttime tics, and sleep and chronotype in relation to tic and co-occurring symptoms in adults with persistent tic disorders (PTDs), including Tourette's disorder (TD).

Methods: One hundred twenty-five adult internet survey respondents rated sleep history, sleep, chronotype, tic severity, impairment, ADHD, obsessive-compulsive symptoms, anxiety, depression, and emotional and behavioral dyscontrol.

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Ethics Approval Statement: Study procedures were approved by the University of California, Los Angeles Medical Institutional Review Board 3 and carried out in accordance with the American Psychological Association Ethics Code.

Patient Consent Statement: All participants read an Institutional Review Board-approved consent form and indicated consent prior to completion of study procedures.

Results: Bruxism, insomnia, tic-related difficulty falling asleep, and melatonin use were commonly endorsed. Sleep disturbance correlated with impairment, obsessive-compulsive symptoms, and emotional and behavioral dyscontrol. Eveningness correlated with vocal and total tic severity only in TD. Controlling for age and sex, age, impairment, and obsessive-compulsive symptoms predicted sleep disturbance, and age and tic severity predicted chronotype.

Conclusions: Impairment and obsessive-compulsive symptoms play a role in sleep disturbance in adults with PTDs, and may be intervention targets. Eveningness relates with tic severity, which may suggest the utility of interventions to advance chronotype.

Keywords

Tourette syndrome; obsessive compulsive disorder; impairment; sleep; chronotype

Tourette's disorder (TD) and other persistent tic disorders (PTDs) are chronic, neurological conditions involving repetitive, involuntary motor tics and/or vocal tics persisting for more than one year (APA, 2013). PTDs run on a spectrum, with persistent motor tic disorder and persistent vocal tic disorder associated with lower severity and TD related with increased severity (Claudio-Campos et al., 2021). PTDs are known to disproportionately affect males, with a ratio of 3-4:1 in childhood and somewhat less skewed ratio of 2:1 in adulthood (Levine, Szejko, & Bloch, 2019; Robertson et al., 2017). Tics typically emerge during childhood, between 4 and 8 years of age (Hirschtritt et al., 2015), with maximal tic severity reached between 10 and 12 years (Leckman, King, & Bloch, 2014). In the majority of cases, tics decrease in severity across adolescence such that they reach minimal to mild levels by early adulthood. However, for a number of individuals, tics do not follow this remitting course, and instead remain at moderate to heightened levels across adulthood (Bloch & Leckman, 2009). PTDs may elicit substantial interference in an array of domains, including emotional, social, academic, occupational, and physical functioning (Conelea et al., 2013; Jalenques et al., 2012). Alongside tics, ADHD and OCD are the most common comorbid conditions (Hirschtritt et al., 2015). Additionally, co-occurring affective disorders, including anxiety and depression increase with advancing age, becoming more prominent in adolescents and adults with PTDs (Bloch & Leckman, 2009; Groth, Debes, Rask, Lange, & Skov, 2017). Further, rage attacks and deficits in emotion regulation are common in both children and adults with PTDs (Drury, Wilkinson, Robertson, & Channon, 2016; Müller-Vahl et al., 2020).

Along with the aforementioned comorbid psychiatric conditions, sleep disturbance frequently presents in PTDs (Kirov, Becker, & Rothenberger, 2014). The most common sleep challenges among adults with PTDs include delays in sleep onset, difficulties with sleep maintenance (i.e., nighttime awakenings), abnormal limb movements and tics during sleep, parasomnias (i.e., nightmares, sleep walking, sleep talking), and daytime sleepiness (Cohrs et al., 2001; Drake, Hietter, Bogner et al., 1992; Jiménez-Jiménez, Alonso-Navarro, García-Martín, & Agúndez, 2020). Both subjective and objective (polysomnography) studies have contributed to understanding of the nature of sleep disturbance in TD. However, there is limited information on rates of sleep disorders in this population. Sleep disorders in general occur at rates as high as 80% (Jiménez-Jiménez et al., 2020). However, findings stem primarily from child or mixed child and adult samples; and estimates of rates of

multiple sleep disorders within a given sample of adults with PTDs are lacking. Findings from a sample of 58 adolescents and adults (15–25 years) with PTDs showed the most commonly endorsed sleep disturbances were nightmares (10.3%), difficulty falling asleep (5.2%), and difficulty staying asleep (5.2%; Erenberg, 1985). And among 245 adults with PTDs, difficulty falling asleep (68.2%) and staying asleep (42.5%) were highly endorsed (Wand, Matazow, Shady, Furer, & Staley, 1993). In contrast with children with PTDs, adults appear to report lower rates of parasomnias (Barabas, Matthews, & Ferrari, 1985; Wand et al., 1993). Therefore, it is important to examine rates of sleep disorders in adult samples independently from child samples. Documentation of the most commonly co-occurring sleep disorders in adults with PTDs may provide clues regarding the pathophysiology of PTDs, based on existing knowledge of the etiology of sleep disorders.

Sleep disturbance may prompt adults with PTDs to seek prescription or over-the-counter sleep medications – the efficacy of which is unknown in PTD samples. Medications to aid sleep onset and maintenance are used at a rate of 8.2% among U.S. adults (QuickStats, 2019). Population-based estimates of prescription sleep medication use are somewhat lower at 3%−4%, with zolpidem and trazodone, being most common (Bertisch, Herzig, Winkelman, & Buettner, 2014; Chong, Fryer, & Gu, 2013). Over-the-counter sleep medication use is endorsed at a higher rate of 10% (Johnson, Roehrs, Roth, & Breslau, 1998), with melatonin commonly used (Clarke, Black, Stussman, Barnes, & Nahin, 2015). Sleep medications can have adverse effects (e.g., memory impairment, daytime sedation), and over-the-counter dietary supplements like melatonin are not approved by the Food and Drug Administration for any purpose (Matheson & Hainer, 2017). Further, melatonin product quality is highly variable (Erland & Saxena, 2017). Knowledge regarding the rates of specific sleep disorders and sleep medication use in adults with PTDs would inform understanding of the potential assessment and treatment needs of this population.

Sleep and wake patterns are regulated by the homeostatic sleep system, which produces rising sleep pressure the longer one has been awake, and circadian rhythms, which influence the timing of sleep and wake patterns, across approximately 24 hours (Borbély, Daan, Wirz-Justice, & Deboer, 2016). Broadly, sleep disturbance and evening chronotype (a measure of one's preference or pattern surrounding sleep and physical activity across a 24-hour period; Roenneberg, 2015) are present across a number of psychiatric disorders (Freeman, Sheaves, Waite, Harvey, & Harrison, 2020; Kivelä, Papadopoulos, & Antypa, 2018; Taylor & Hasler, 2018). However, studies investigating chronotype or circadian rhythms in individuals with PTDs are scant. To date, the only investigation of this topic in PTDs showed increased evening chronotype, but no objective circadian phase delay in adults with PTDs relative to healthy controls (Ricketts et al., 2022). Sleep disturbance and evening chronotype increase risk for future adverse mental and physical health problems (Hale, Troxel, & Buysse, 2020; Partonen, 2015), and interrelate with psychiatric symptom severity, often in a bidirectional manner (Freeman, Sheaves, Waite, Harvey, & Harrison, 2020; Taylor & Hasler, 2018).

The degree to which sleep disturbance and evening chronotype relate with tic severity is not yet clear. Across child and adult samples, a few studies have shown an association between sleep disturbance and daytime tic severity (Cohrs et al., 2001; Romano, Cundari, Bruni, & Cardona, 2004; Sambrani et al., 2016), whereas several studies have not (Konstanecka-

Endress et al., 2003; Modafferi, Stornelli, Chiarotti, Cardona, & Bruni, 2016; Pringsheim et al., 2020; Ricketts et al., 2022; Storch et al., 2009). With regard to chronotype, it was not related with tic severity in a small sample of adults with PTDs (Ricketts et al., 2022). Although tic severity has been examined in relation to these constructs, the extent to which nighttime tic symptoms relate with sleep and chronotype is not known. Certainly, subjective and objective studies show tics are present during sleep at a rate ranging from 14% to 100% (Jiménez-Jiménez et al., 2020). However, we do not know the significance of their presence in terms of sleep and chronotype. Tics occurring near bedtime may interfere with falling asleep or prompt eveningness through delayed bedtimes or increased evening exposure to light, which can delay circadian timing (Bijlenga, Vollebregt, Kooij, & Arns, 2019; Coles & Sharkey, 2011). Conversely, nighttime-tic-related or general sleep disturbance or evening chronotype may exacerbate tics by disrupting neural processes involved in tic inhibition (Kirov, Becker, & Rothenberger, 2014). Additionally, as tics fluctuate across the day (Leckman, 2003), the association between nighttime tics and general tic severity is unclear. Although an examination of directionality is outside the scope of this investigation, an enhanced understanding of tics before and during sleep and their relationship with sleep, chronotype, and general tic severity may improve understanding of relationships among these dimensions.

Beyond tic symptoms, there are a number of common co-occurring psychiatric symptoms relevant to sleep and chronotype. For example, ADHD, which is highly concomitant with PTDs, is often related with sleep problems and evening chronotype among adults (Coogan & McGowan, 2017; Snitselaar, Smits, van der Heijden, & Spijker, 2017). OCD too has been reliably linked with sleep disruption, but the relationship between OCD and evening chronotype or delayed sleep-wake timing has been less consistent across studies (Coles, Schubert, Stewart, Sharkey, & Deak, 2020; Cox & Olatunji, 2019; Cox, Parmar, & Olatunji, 2019). Depression, anxiety, emotion dysregulation, and disruptive behavior – also comorbid with PTDs – are commonly related with sleep problems and eveningness (Alvaro, Roberts, & Harris, 2013; Alvaro, Roberts, & Harris, 2014; Au & Reece, 2017; Gao, Shen, Qin, & Zhang, 2020; Kamphuis & Lancel, 2015; Schlarb, Sopp, Ambiel, & Grünwald, 2014; Vandekerckhove & Wang, 2018; Watts & Norbury, 2017). Psychiatric symptoms prompt varying degrees of impairment in daily functioning across individuals (Tanner et al., 2019). Degree of functional impairment may serve to indicate the extent to which symptoms may also interfere with sleep patterns (Muazzam & Ahmad, 2017). Further, demographic factors, including age and sex – implicated in PTD occurrence and course – influence sleep and chronotype. Chronotype shifts toward eveningness during puberty and subsequently advances with increasing age (Roenneberg et al., 2004). Age-related sleep changes encompass reduced sleep duration, increased nighttime awakenings and time spent awake during the night (Li, Vitiello, & Gooneratne, 2019). Sex differences appear to interact with age to affect chronotype, as there is increased eveningness in young men relative to women, but less eveningness in older men relative to women (Fischer, Lombardi, Marucci-Wellman, & Roenneberg, 2017; Randler & Engelke, 2019). Additionally, women report increased sleep disturbance and poorer sleep quality and have higher rates of insomnia (Baker, Yüksel, & de Zambotti, 2020). Knowledge of the contributing factors to sleep disturbance and chronotype in adults with PTDs may enhance our clinical understanding

of pathways influencing models of PTDs, provide clinical cues which may serve as flags during assessment to indicate specific sleep or chronotype patterns, and foster identification of treatment targets in adults with PTDs.

In response to the limited research on sleep disturbance in adults with PTDs, and the absence of studies examining chronotype in PTDs, the aims of the present study were to obtain rates of lifetime sleep disorders and sleep medication use among adults with PTDs, examine the degree to which nighttime tics are associated with increased sleep disturbance, evening chronotype, and general tic severity, evaluate the degree to which sleep disturbance and evening chronotype are related with tic severity, co-occurring psychopathology, and impairment, and explore the most robust cross-sectional clinical predictors of sleep disturbance and chronotype, after accounting for age and sex. As research suggests persistent motor or vocal tic disorders and TD run on a severity continuum (Claudio-Campos et al., 2021), cross-sectional analyses were performed in adults with PTDs and a subsample with only TD.

Method

Participants

Participants were 125 adults aged 18 to 76 (M = 30.60, SD = 11.88) with TD (n = 115, 92.0%), persistent motor tic disorder (n = 9, 7.2%), and persistent vocal tic disorder (n = 1, 0.8%) who completed an internet survey examining sleep and chronotype in relation to tic and other clinical symptoms. Participants were recruited through patient advocacy and support websites. Less than half of the sample (n = 53, 44.2%) were male, and the majority (n = 111, 91.0%) were white. See Table 1 for additional sample demographics. Approximately 70.2% (n = 85) reported lifetime tic medication use (see Table 1), and 46.3% (n = 56) endorsed current tic medication use (see Table 2). There were no significant differences in sleep disturbance between adults who reported current tic medication use (M = 57.10, SD = 7.77) and those who did not (M = 55.27, SD = 7.05, p = .24, d = 0.25). There were also no significant differences in chronotype between participants endorsing current use of tic medication (M = 45.82, SD = 10.62) relative to those who did not (M = 44.96, SD = 10.93, p = .71, d = 0.08). The majority of the sample (n = 118, 98.3%) endorsed the presence of one or more lifetime psychiatric disorders (see Table 3), with generalized anxiety disorder (n = 61, 50.4%), ADHD (n = 58, 48.3%), OCD (n = 49, 41.2%), and major depressive disorder (n = 49, 40.5%) most commonly reported.

Measures

Demographic and Clinical Characteristics.—Participants completed questions regarding demographics, and psychiatric and medical history, and tics before and during sleep. Participants were asked about lifetime tic medication using the following question: *"Have you ever received any of the following treatments [i.e., medication] for tics?"* The survey assessed current tic medication use via a yes or no checklist of 44 tic medications, which included the following question: *"Are you currently taking any of the following medications to treat tics?*" The individual yes or no responses were aggregated to form a summary variable (see Table 1). In addition, the survey assessed use of current medications

for sleep with the following question: *"Are you currently taking any of the following medications (prescribed or over-the-counter) to help you sleep?"* Participants also endorsed the presence of lifetime psychiatric disorders using the following questions: *"Have you ever been diagnosed with any of the following psychiatric disorders by a health professional?"* Lifetime sleep disorders were assessed via the following item: *"Have you ever been diagnosed with any of the following sleep disorders by a health professional?"* Further, participants completed a yes or no question regarding the presence of tics before sleep: *"In the past month have your tics made it hard for you to fall asleep?"* This was followed by an item evaluating the occurrence of tics during sleep: *"In the past month have you displayed tics during sleep (i.e., after falling asleep)?"* Response options were "Yes" or "Not that I know of." Those endorsing yes to this item were asked "How do you know you have been displaying tics during sleep? Response options were multiple choice and included: "A parent told me," "A bed partner told me," or "Other."

Patient Reported Outcomes Measurement Information System (PROMIS) Sleep Disturbance, Short Form (SD).—The SD (Yu et al., 2012) is an abbreviated 8-item measure of sleep disturbance in the past seven days. The measure includes items evaluating sleep restlessness, satisfaction with sleep, degree to which sleep is refreshing, difficulty falling asleep, difficulty staying asleep, trouble sleeping, sufficiency of sleep duration, and sleep quality. Four items are reverse scored. Items are summed and standardized to a T score. The general population mean is a T score of 50, with higher values indicating more sleep disturbance. The measure exhibits high reliability and good convergent validity (Yu et al., 2012).

The Morningness-Eveningness Questionnaire.—The MEQ (Horne & Östberg, 1976) is a 19-item self-report measure of morning and evening preferences for sleep, wake, alertness, and activity times over the prior month. The measure yields a total score. Higher scores represent greater morningness and lower scores represent greater eveningness. The measure demonstrates good internal consistency, and good convergence with other measures of chronotype, and biological circadian markers, including dim light melatonin onset, and body temperature (Duffy, Rimmer, & Czeisler, 2001; Horne & Östberg, 1976; Kantermann, Sung, & Burgess, 2015; Zavada et al., 2005).

The Adult Tic Questionnaire (ATQ).—The ATQ (Abramovitch et al., 2015) is a self-report measure of tic severity. Adults endorse the presence of 14 common motor tics and 13 common vocal tics over the past week. For each endorsed tic, patients indicate the frequency and intensity using an independent 1- to- 4 scales. Frequency and intensity ratings are summed for motor and vocal tics separately, yielding motor tic and vocal tic severity scores, respectively. These scores are summed to produce a total tic severity score. The ATQ exhibits excellent internal consistency, good test-retest reliability, strong convergent validity, and good discriminant validity (Abramovitch et al., 2015).

The Sheehan Disability Scale (SDS).—The SDS (Sheehan, 1983) is a reliable and valid, brief, three-item self-report measure of impairment associated with psychiatric disorders. The measure assesses the degree to which symptoms interfere with occupational,

social, and family/home functioning. Higher scores indicate greater impairment (Leon, Shear, Portera, & Klerman, 1992; Sheehan, 1983). This measure was administered directly following the ATQ.

The Adult ADHD Self-Report Screening Scale for DSM-5 (ASRS-5).—The ASRS-5 (Ustun et al., 2017) is a brief, six-item measure of DSM-5 ADHD symptoms over the past 6 months. Items are rated using a 0- to 4- point scale, and can yield a total score from 0 to 24. Higher scores indicate greater ADHD symptom severity. The measure has high specificity and positive predictive value in relation to ADHD diagnosis (Ustun et al., 2017).

The Obsessive-Compulsive Inventory-Revised (OCI-R).—The OCI-R (Foa et al., 2002) is an 18-item measure of obsessive-compulsive symptom severity over the past month. Items are rated on a 0- to- 4-point scale. The measure yields scores for six subscales and an overall total score, with higher scores indicative of greater symptom severity.

Patient Health Questionnaire-4 (PHQ-4).—The PHQ-4 (Kroenke, Spitzer, Williams, & Lowe, 2009) is a 4-item screening measure of anxiety and depression symptoms, with two items assessing each dimension. Items are rated on a 0- to- 3 scale and higher scores represent greater severity. The measure exhibits good internal consistency and correlates with indices of physical and mental health (Khubchandani, Brey, Kotecki, Kleinfelder, & Anderson, 2016; Kroenke et al., 2009).

NeuroQol Emotional and Behavioral Dyscontrol, Short Form.—NeuroQol Emotional and Behavioral Dyscontrol, Short Form (Cella et al., 2012) is an abbreviated 8-item self-report measure of disinhibition, emotional lability, irritability, impatience, and impulsivity in the past 7 days. The scale was developed for, and validated in individuals with neurological conditions. The measure has excellent internal consistency, and correlates highly with the long version. Higher scores indicate poorer emotional and behavioral dyscontrol.

Procedure

Participants completed the survey via a link hosted on Research Electronic Data Capture (REDCap) from February 2019 to July 2020. Interested adults read a web-based IRB-approved consent document and indicated study agreement or disagreement by checking a box. Two hundred thirteen participants indicated study agreement. Of the 213 who agreed to participate, 146 (68.5%) initiated the survey. Eligibility was determined through separate survey questions. Of the 146 who initiated the survey, 21 (14.4%) were screened out for 1) current age < 18 years ($n = 3$), 2) lack of endorsement ($n = 9$) of lifetime TD or PTD diagnosis (i.e., *"Have you ever been diagnosed with Tourette's Disorder (Tourette Syndrome), Persistent (Chronic) Motor Tic Disorder or Persistent (Chronic) Vocal Tic Disorder by a health professional?"* 3) no indication of diagnostic type ($n = 13$), and 4) lack of tic onset prior to 18 years of age ($n = 9$), assessed via two separate questions dispersed across the demographics section: *"Did your tics first begin before the age of 18?"* and *"How old were you when your tics first began?"* Reported n's are not mutually exclusive. Exclusion criteria were applied after data collection was complete, yielding 125

participants. Participants were presented with a separate link to provide their email address in order to enter into a drawing to receive one of 20 $50 gift cards. Survey participation was not required for entry into the drawing. Upon completion of enrollment, 20 email addresses were randomly selected from those who entered the drawing in order to provide electronic gift cards.

Statistical Analyses

Analyses were conducted using SPSS 27.0. Missing value analysis indicated that 22.34% of the values for variables used in correlation and regression analyses were missing. Multiple imputation using predictive mean matching was conducted to address missing data, as the data met only one of the two assumptions required for Bayesian multiple imputation, which include data missingness at random, and a parametric data distribution (Enders, 2017; Kleinke, 2017). Little's test of missing completely at random (MCAR), which tests the null hypothesis that data are MCAR, revealed a p-value greater than .05 ($\chi^2(185) = 190.833$, $p = .37$), indicating that we fail to reject the null hypothesis specifying that data are MCAR (Li, 2013). However, data did not meet the parametric distribution assumption, as data were not normally distributed. Similar to Bayesian multiple imputation, predictive mean matching generates multiple versions of the data, each with different imputed values randomly drawn from a distribution of replacement values generated through a regression model (Enders, 2017). However, unlike Bayesian multiple imputation, predictive mean matching imputes an actual observed value drawn from a pool of $k > 1$ near-neighbor values; thus, it is better able to preserve the original data distribution and interrelationships among variables (Kleinke, 2017). A near-neighbor value of 5 was selected as it is deemed an appropriate default (Kleinke, 2017). Per guidance, 10 imputations were performed to produce efficient missing data estimates (Van Buuren, 2018). Data were imputed at the subtotal and total score level, as this has been shown to outperform imputation at the item level in small sample sizes ($n \leq 200$; Rombach, Gray, Jenkinson, Murray, & Rivero-Arias, 2018).

Descriptive statistics, including means and frequencies are presented on unimputed data to clinically characterize the sample and describe rates of current sleep medication use, lifetime sleep disorders, and nighttime tics. Per guidelines, descriptive statistics are reported on unimputed data (Hardt, Herke, Brian, & Laubach, 2013). Independent samples t-tests were also performed on unimputed data to compare sleep, chronotype, and tic severity in adults endorsing tic-related difficulty falling asleep, and tics during sleep relative to those who did not. Cohen's *d* effect size estimates are reported and can be interpreted as follows: 0.2 (small), 0.5 (medium), and 0.8 (large; Cohen, 1988). Pearson bivariate correlations were performed on imputed data to evaluate associations of sleep and chronotype with motor, vocal, and total tic severity, impairment, ADHD, obsessive-compulsive symptoms, anxiety, depression, and emotional and behavioral dyscontrol separately for the full sample (i.e., adults with PTDs), and a subsample of adults with TD. Linear regression was performed on each imputed data set to explore the degree to which, total tic severity, impairment, ADHD, anxiety, depression, and emotional and behavioral dyscontrol predicted sleep disturbance and chronotype, with age and sex included as covariates in the full sample with PTDs and subsample with TD. Then linear regression was repeated using model selection techniques outlined by Brand (1999) to account for variation in significant sets of variables between

data sets and roughly correct for multiple testing (van Buuren, 2018). First, stepwise linear regression was performed on each data set with a p-value of .05 used for entering variables and .10 used for removal. Variables found to be significant ($p < .05$) across half or more of the 10 imputed data sets were included in a new model. Backward elimination was applied to this new model by removing variables with a p-value larger than .05 to establish the final model. The variance-inflation factor (VIF), which evaluates multicollinearity among predictors, is reported. Scores lower than 10 are indicative of a lack of collinearity among the independent variable and other variables within the model (Mela & Kopalle, 2002). Adjusted R^2, a measure of the predictive power of a model adjusted for the number of predictors in the model, is reported. A higher value indicates that the predictive power of the model is increased based on the predictors in the model (Austin & Steyerberg, 2015). Cohen's f^2 is reported as an effect size measure may be interpreted according to the following guidelines: .02 (small), .15 (moderate), and .35 (large) (Cohen, 1988). Pooled regression statistics are reported.

Results

Lifetime Sleep Disorders and Current Sleep Medication Use

Almost two-thirds ($n = 76$, 63.3%) of the sample endorsed one or more lifetime sleep disorders (see Table 3), with bruxism ($n = 35$, 29.2%), insomnia (n = 29, 24.0%), nightmares ($n = 21$, 17.5%), and restless legs syndrome ($n = 15$, 12.5%) being most common. Forty percent ($n = 48$) reported current use of prescribed or over-the-counter medication for sleep problems (see Table 2). The most frequently endorsed sleep medications were melatonin ($n = 32$, 27.1%), and diphenhydramine (Benadryl, Unisom sleep gels, etc; $n = 13$, 11.1%).

Tic-related Difficulty Falling Asleep and Tics During Sleep

Just over half the sample ($n = 69$, 56.1%) endorsed that tics made it hard to fall asleep (see Table 1). Participants endorsing that tics made it hard to fall asleep had significantly higher sleep disturbance scores ($n = 50$, $M = 58.16$, $SD = 6.58$) than those who did not ($n = 43$, $M = 53.74$, $SD = 7.67$; $t(91) = 2.99$, $p = .004$, $d = 0.62$. There were no significant differences in chronotype between those who endorsed tic-related interference with falling asleep ($n = 48$, $M = 44.38$, $SD = 11.35$) and those who did not ($n = 42$, $M = 46.43$, $SD = 10.04$; $t(88) = -0.90$, $p = .37$, $d = -0.19$). Participants who endorsed tic-related difficulty falling asleep had significantly higher total tic severity ($n = 53$, $M = 67.15$, $SD = 34.48$) relative to those who did not ($n = 35$, $M = 42.26$, $SD = 22.58$; $t(86.0) = 4.09$, $p < .001$, $d = 0.82$).

Approximately 21% (n=26) of the sample endorsed the display of tics during sleep (see Table 1). Of those endorsing the occurrence of tics during sleep, 7.7% ($n = 2$) reported knowing because a parent had told them, 69.2% ($n = 18$) because a bed partner told them, and 23.1% ($n = 6$) due to finding out by some 'other' means. There were no significant differences in sleep disturbance between adults who endorsed the display of tics during sleep ($n = 18$, $M = 58.94$, $SD = 7.73$) relative to those who reported no occurrence to their knowledge ($n = 75$, $M = 55.44$, $SD = 7.22$; $t(91) = 1.82$, $p = .07$, $d = 0.48$). There were no significant differences in chronotype between adults who reported the presence of tics during sleep ($n = 18$, $M = 46.00$, $SD = 12.10$) and those who did not ($n = 72$, $M = 45.17$,

SD = 10.47; *t*(88) = 0.29, *p* = .77, *d* = 0.08). There were also no statistically significant differences in tic severity between adults who endorsed tic occurrence during sleep (*n* = 17, *M* = 73.35, *SD* = 46.62) and those who did not (*n* = 71, *M* = 53.39, *SD* = 27.25; *t*(18.70) = 1.70, *p* = .11, *d* = 0.63).

Pearson Bivariate Correlations between Sleep, Chronotype, and Clinical Symptoms in Full Sample and TD Subsample

In adults with PTDs (i.e., TD, persistent motor tic disorder, or persistent vocal tic disorder), there were significant, positive correlations (see Table 4) between sleep disturbance and impairment (*p* = .01), obsessive-compulsive symptoms (*p* = .002), and emotional and behavioral dyscontrol (*p* = .001). There were no significant correlations between sleep disturbance and other measures (*p* = .08 – .29). In the TD subsample, sleep disturbance was significantly, and positively associated with impairment (*p* = .01), obsessive-compulsive symptoms (*p* = .01), and emotional and behavioral dyscontrol (*p* = .004). There were no significant correlations between sleep disturbance and other measures (*p* = .11 – .33).

There were no significant correlations between chronotype and clinical measures in the full sample (*p* = .07 – .85; see Table 4). In the TD subsample, there were significant, negative correlations between chronotype and vocal (*p* = .03), and total (*p* = .01) tic severity, such that a lower MEQ score (representing increased eveningness) was associated with higher tic severity. Chronotype was not significantly correlated with any other measures in the TD subsample (*p* = .07 – .96).

Multiple Linear Regression Analysis of Clinical Predictors of Sleep Disturbance and Chronotype after controlling for Age and Sex in the Full Sample and TD Subsample

In the full sample (see Table 5) none of the measures in the full model significantly predicted sleep disturbance. In the final model age (*p* = .04) and obsessive-compulsive symptoms (*p* = .003) significantly predicted sleep disturbance. In the TD subsample (see Table 5), no measures significantly predicted sleep disturbance in the full model, but in the final model age (*p* = .04) and impairment (*p* = .01) significantly and positively predicted sleep disturbance.

In the full sample (see Table 6) there were no significant predictors of chronotype in the full model. Age was the only significant predictor (*p* = .03) of chronotype in the final model (i.e., older age predicted increased morningness). In the TD subsample (see Table 6), age positively predicted chronotype (*p* = .04), and tic severity negatively predicted chronotype (*p* = .03), such that increased tic severity was associated with greater eveningness. In the final model, age (*p* = .03) positively predicted chronotype (i.e., predicted morningness), and tic severity (*p* = .02) negatively predicted chronotype.

Discussion

The present study evaluated rates of lifetime sleep disorders and current sleep medication use, tic-related difficulty falling asleep and tics during sleep in relation to sleep, chronotype, and tic severity, and associations of sleep and chronotype with tic severity, co-occurring symptoms and impairment; and explored clinical predictors of sleep and chronotype,

accounting for age and sex in adults with PTDs. Findings showed 63% of the sample endorsed one or more lifetime sleep disorders, with bruxism, insomnia, nightmares and restless legs syndrome being most common. Forty percent endorsed current sleep medication use, with melatonin and diphenhydramine most frequently cited. Just over half of participants (56%) endorsed tic-related difficulty falling asleep, which was associated with increased general sleep disturbance and tic severity relative to those not endorsing tic-related difficulty falling asleep; and 21% reported tic occurrence during sleep. In both the full sample with PTDs and subsample with TD, sleep disturbance was associated with functional impairment, obsessive-compulsive symptoms, and emotional and behavioral dyscontrol, whereas eveningness was associated with vocal and total tic severity only in the TD subsample. Older age and obsessive-compulsive symptoms were the strongest predictors of sleep disruption in PTDs, and age and impairment were the strongest predictors of sleep disturbance in TD. Across the PTD and TD samples, older age predicted increased morningness, and within TD, tic severity predicted eveningness.

Lifetime Sleep Disorders and Current Sleep Medication Use

Sleep bruxism, a parasomnia involving teeth grinding, was the most commonly cited (29%) lifetime sleep disorder. The present rate is higher than the 3% to 10% found in small mixed child and adult PTD samples (Drake, Hietter, Bogner, & Andrews, 1992; Jankovic & Rohaidy, 1987), the 19% found in a small sample of youth with PTDs (Modaffieri et al., 2016), and 12.5% found in a representative general population sample (Maluly et al., 2013). The high rates of insomnia and nightmares align with those found in prior adolescent and adult PTD samples (Erenberg, 1985; Wand et al., 1993), and the rate of restless legs syndrome (12.5%) is on par with the 10% diagnosed with this condition in a mixed child and adult sample with PTDs (Lespérance et al., 2004). Consistent with prior literature, findings highlight the co-occurrence of disorders of sleep initiation and maintenance, parasomnias, and sleep-related movement disorders in adults with PTDs and align with the framing of PTDs as disorders of arousal (Glaze, Frost, & Jankovic, 1983; Jiménez-Jiménez et al., 2020). Research is needed to establish the pathophysiological significance of patterns of high co-occurrence of PTDs with specific sleep disorders. For example, variants in the *BTBD9* gene, associated with restless legs syndrome and periodic limb movements, are also related with PTDs (Jean-Baptiste-Rivière et al., 2009). Further, it has been suggested that iron deficiency, underlying restless legs syndrome, is also implicated in PTDs (Ghosh & Burkman, 2017).

Current melatonin use was highly endorsed among the sample. The steady increase in popularity of this supplement for sleep problems through the years (Clarke, Black, Stussman, Barnes, & Nahin, 2015) may partially explain this high rate. Additionally, the frequent use of melatonin to address sleep concerns in other neurodevelopmental conditions, such as ADHD, and autism spectrum disorders, and its occasional positive impact on behavioral functioning in these conditions (Rzepka-Migut & Paprocka, 2020) may also prompt its use among individuals with PTDs. Melatonin serves as a soporific agent when administered approximately 30 minutes prior to bedtime, or a circadian phase advancing agent when administered about 5 hours prior to bedtime (Burgess & Emens, 2016). Meta-analyses indicate that the most prominent sleep-related effect of melatonin is reduced sleep

onset latency (Brzezinksi et al., 2005; Ferracioli-Oda, Quawasmi, & Bloch, 2013). Among adults, it appears well-tolerated over short-term use, with mild side effects (e.g., daytime sleepiness, dizziness, headache) reported (Andersen, Gögenur, Rosenburg, & Reiter, 2016. However, use amongst pregnant and breast-feeding women is ill-advised due to lack of testing; and short-term use in children should be monitored carefully due to the theorized role of endogenous melatonin in pubertal development (Andersen et al., 2016; Riha, 2018). As over-the-counter melatonin supplement quality is highly variable (Erland & Saxena, 2017), studies are needed to evaluate the efficacy of melatonin for sleep in PTDs.

Tic-related Difficulty Falling Asleep and Tics During Sleep

Tic-related difficulty falling asleep was a commonly cited clinical characteristic, and was significantly related with tic severity and sleep disturbance. Although findings must be interpreted cautiously, they indicate alignment among these three clinical features. One could envision that an individual with increased tic severity may have heightened tic-related challenges with the settling required for sleep onset, providing one of several potential contributing factors to general sleep disturbance in this population. It is also possible that neural processes within individuals with PTDs are related with susceptibility for development of both tics and sleep disruption, and nighttime tics may exacerbate existing sleep disturbance (Kirov et al., 2014). Findings highlight the need for clinical attention to evening and bedtime tics, particularly among individuals reporting high tic severity or general sleep disturbance. Tic-related difficulty falling asleep was not related with chronotype, which counters the hypothesis that tic-related challenges falling asleep may be implicated in evening chronotype in adults with PTDs. Approximately 21% of adults in the sample endorsed the presence of tics during sleep, which falls within the range of 14% to 23% reported per prior subjective studies (Champion, Fulton, & Shady, 1988; Erenberg, 1985; Jankovic & Rohaidy, 1987). The lack of association between tics during sleep and tic severity and sleep-wake patterns may be a function of under-endorsement of this item due to lack of knowledge of tic occurrence during sleep. It has been suggested that the presence of tics during sleep may be related to reduced activation of the prefrontal cortex during the sleep period (Kirov et al., 2014). Future research is needed to understand the clinical and neural significance of tic occurrence during sleep.

Sleep and Chronotype in Relation to Clinical Characteristics

Impairment, obsessive-compulsive symptoms, and emotional and behavioral dyscontrol were associated with sleep disturbance in the present sample. Findings are consistent with prior research showing relationships between these dimensions and sleep disturbance (Cox, Parmar, & Olatunji, 2019; Nota, Sharkey, & Coles, 2015; Kamphuis & Lancel, 2015; Vandekerckhove & Wang, 2018), and may suggest incorporating direct clinical intervention for these factors during treatment of PTDs in adults could be useful. ADHD, which is frequently associated with sleep problems in youth with PTDs (Modafferi et al., 2016; Pringsheim, Nosratmirshekarlou, Doja, & Martino, 2021; Stephens et al., 2013; Storch et al., 2009), did not rise to significance in the current sample. The significantly lower rates of comorbid ADHD in adults with PTDs relative to children (Jankovic, Gelineau-Kattner, & Davidson, 2010) may contribute to the lack of association. Although an association between tic severity and sleep disturbance was anticipated, the lack of significant relationship

found here is consistent with prior mixed findings (Cohrs et al., 2001; Kirov, Kinkelbur, Banaschewski, & Rothenberger, 2007; Kostanecka-Endress et al., 2003; Modafferi et al., 2016; Pringsheim et al., 2021; Romano et al., 2004). Neither depression nor anxiety rose to statistical significance in their associations with sleep disturbance in the present sample. This was contrary to expectation, as anxiety and depression are common in adults with PTDs (Hirschtritt et al., 2015), and strongly associated with sleep disturbance in general (Cox & Olatunji, 2020; Murphy & Peterson, 2015).

Tic severity was the only clinical factor associated with eveningness and only in the TD subsample. This is contrary to findings showing no correlation between clinician-rated tic severity and chronotype in a small sample of adults with PTDs (Ricketts et al., 2022). The significance and directionality of this relationship is unclear. The specificity of this relationship to adults with TD rather than the broader category of PTDs may relate to a higher degree of severity associated with TD relative to persistent motor or vocal tic disorders (Claudio-Campos et al., 2021). Although tic-related difficulty falling asleep was not related to chronotype, it is possible that some aspect of high tic severity relates with evening chronotype, maybe through bedtime procrastination and increased evening light exposure (Taylor & Hasler, 2018). Perhaps evening bouts of tics lead to delaying of bedtimes. There may also be social benefits to remaining awake later at night (e.g., reduced self-consciousness) that might maintain eveningness patterns. Additionally, eveningness may relate with tic severity through mediating factors, such as impulsivity and executive function, which are implicated in PTDs (Kuula et al., 2017; Morand-Beaulieu et al., 2017; Taylor & Hasler, 2018). Further, there may be shared neural processes linking eveningness and tic occurrence (Taylor & Hasler, 2018). Of particular relevance to PTDs, which are associated with deficits in dopaminergic functioning (Buse, Schoenefeld, Münchau, & Roessner, 2013), it has been suggested that the suprachiasmatic nucleus (which is located in the hypothalamus and regulates our circadian rhythm) and dopaminergic system activity, have bidirectional influences (Mendoza & Challet, 2014). Additionally, one study found that dopaminergic activity within the striatum followed a circadian rhythm, and that the peak of striatal dopaminergic activity coincided with peak activity in a rat model of TD (Ji, Wu, & Zhang, 2016). Taken together, these findings may suggest a role for circadian rhythms in tic expression. The association found here is consistent with the body of literature supporting both the role of eveningness in psychiatric symptoms broadly (Taylor & Hasler, 2018), and conditions commonly comorbid with PTDs (e.g., OCD, ADHD, anxiety, depression, emotional and behavioral dysregulation). Nevertheless, eveningness was not associated with these co-occurring psychiatric symptoms as they occurred in the present sample. The lack of association between eveningness and co-occurring psychiatric symptoms is surprising, and these relationships require further testing in future studies. Finally, age was consistently related with sleep disruption and chronotype across regression models. Older age was associated with greater sleep disturbance and increased morning chronotype. This indicates that sleep and chronotype patterns in adults with PTDs are consistent with reported age trends in the general population (Li et al., 2019; Roenneberg et al., 2004). Age trends in sleep are corroborated by a prospective longitudinal follow-up study in a large clinical sample of individuals with PTDs (Groth et al., 2017).

Limitations, Future Research, and Clinical Implications

Although informative, the present study has several limitations. Due to the internet survey design, diagnoses could not be confirmed by a health professional. In relation, sleep disorders were not corroborated by objective assessment measures (e.g., actigraphy, polysomnography) or clinician interview. Additionally, as the survey was advertised as pertaining to sleep-wake patterns and PTDs, it may be limited by selection bias, whereby adults with PTDs and co-occurring sleep problems may have been more likely to partake in the survey than those with PTDs without sleep problems. Also, survey items requiring retrospective report introduce recall bias. An additional point is that the survey assessed lifetime, but not current, psychiatric and sleep disorders, which limits our understanding of the current psychiatric and sleep disorder profile of our sample. Such current information would have provided more context for interpreting relationships among measures. Further, the measure of sleep used provides a score for general sleep disturbance, and therefore lacks specificity with respect to type of sleep problems (e.g., difficulty falling asleep, night awakenings, etc.) present. Moreover, we lack an understanding of the directionality of relationships between sleep disturbance/chronotype and clinical symptoms. Prior research in other clinical domains suggests the presence of bidirectional associations (Taylor & Hasler, 2018). Additionally, the measure of tic severity used – the Adult Tic Questionnaire – has a wide scoring range, which heavily weights the number of tics endorsed since patients provide frequency and intensity ratings for each tic independently. Therefore, the presence of a few frequent and intense tics, may produce an equivalent score to many infrequent and mild tics (Abramovitch et al., 2015). Finally, our sample was primarily female, which may limit generalizability of findings to the predominantly male population of individuals with TD at large. Our preponderance of women may be related to the less skewed male to female sex ratio in adulthood relative to childhood among individuals with PTDs (Levine, Szejko, & Bloch, 2019; Schlander, Schwarz, Rothenberger, & Roessner, 2010), and the increased report of sleep problems in women with PTDs and the general population relative to men (Arber, Bote, & Meadows, 2009; Mallampalli & Carter, 2014; Sambrani et al., 2016).

Future studies are needed to repeat this analysis in a sizeable, clinically well-characterized, sample. Research parsing the influence of tic symptoms versus psychiatric comorbidity, and medication on sleep disturbance and chronotype would be beneficial. Emergence of circadian rhythm sleep disorder following psychotropic medication use was documented in a patient with TD (Ayalon, Hermesh, & Dagan, 2002), and psychotropic medications are known to have adverse influences on sleep and circadian rhythms broadly (Doghramji & Jangro, 2016; Oral, Ozcan, Gulec, Selvi, & Aydin, 2011), although this was not found in the present sample. Further, studies examining directionality of associations between tic and co-occurring symptoms and sleep and chronotype would be useful. Longitudinal studies are needed to evaluate these complex relationships among clinical variables in PTDs. Further, studies employing objective measures and controlled designs are needed to examine the pathophysiological significance of these relationships, as it is possible that deficits in neural circuitry may leave one susceptible to both tics and sleep and circadian function.

Findings draw attention to the need for assessment and intervention of sleep disturbance in adults with PTDs. For individuals with tic-related difficulty falling asleep, perhaps use

of clonidine, an alpha-agonist medication used to treat tics with sleep promoting effects (Naguy, 2016), practice of habit reversal training strategies (e.g., competing responses; Woods et al., 2008) or mindfulness-based stress reduction for tics (Kim, Park, & Seo, 2016; Reese et al., 2015) at bedtime may reduce tics in this context. Although speculative, findings may suggest that behavioral treatment of functional impairment (e.g., Living with Tics; McGuire et al., 2015) and obsessive-compulsive symptoms (Ivarsson & Skarphedinsson, 2015; Nordahl, Havnen, Hansen, Öst, & Kvale, 2017) could aid sleep management in adults with PTDs. Alternatively, perhaps sleep intervention could yield improvements in psychiatric symptoms and impairment (Scott et al., 2021). The association found between tic severity and eveningness has implications for examining the degree to which the application of circadian interventions to advance evening chronotype, such as light therapy or exogenous melatonin, may positively influence tic symptoms. An open pilot trial examining two weeks of short-wavelength, wearable morning light therapy for adults with PTDs showed a significant circadian phase advance and small, significant reductions in tic severity, tic-related impairment, anxiety, and daytime sleepiness (Ricketts et al., 2022). Such research requires further investigation in controlled trials.

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Dr. Ricketts has received honoraria and research funding from the Tourette Association of America (TAA), and serves on the TAA Diversity Committee. Dr. Burgess serves on the scientific advisory board (consultant) for Natrol, LLC, a manufacturer of melatonin. Dr. Piacentini has received research support and honoraria from the TAA, and financial support from the TAA Center of Excellence Gift Fund. He has also served on the speakers' bureau of the TAA and the International OCD Foundation. All other authors declare no conflicts of interest.

Data Availability Statement:

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

Abramovitch A, Reese H, Woods DW, Peterson A, Deckersbach T, Piacentini J, Scahill L, & Wilhelm S (2015). Psychometric properties of a self-report instrument for the assessment of tic severity in adults with tic disorders. Behavior Therapy, 46(6), 786–796. 10.1016/j.beth.2015.06.002 [PubMed: 26520221]

Alvaro PK, Roberts RM, & Harris JK (2013). A systematic review assessing bidirectionality between sleep disturbances, anxiety, and depression. Sleep, 36(1), 1059–1068. [PubMed: 23814343]

Alvaro PK, Roberts RM, & Harris JK (2014). The independent relationships between insomnia, depression, subtypes of anxiety, and chronotype during adolescence. Sleep Medicine, 15(8), 934–941. 10.1016/j.sleep.2014.03.019 [PubMed: 24958244]

American Psychiatric Association. (2013). Diagnostic and Statistical Manual of Mental Disorders (5th ed.). Arlington, VA: American Psychiatric Publishing. 10.1176/appi.books.9780890425596.dsm05

Andersen LPH, Gögenur I, Rosenberg J, & Reiter RJ (2016). The safety of melatonin in humans. Clinical Drug Investigation, 36(36), 169–175. 10.1007/s40261-015-0368-5 [PubMed: 26692007]

Arber S, Bote M, & Meadows R (2009). Gender and socio-economic patterning of self-reported sleep problems in Britain. Social Science & Medicine, 68(2), 281–289. 10.1016/j.socscimed.2008.10.016 [PubMed: 19026480]

Au J, & Reece J (2017). The relationship between chronotype and depressive symptoms: A meta-analysis. Journal of Affective Disorders, 218(93), 93–104. 10.1016/j.jad.2017.04.021 [PubMed: 28463712]

Austin PC, & Steyerberg EW (2015). The number of subjects per variable required in linear regression analyses. Journal of Clinical Epidemiology, 68(6), 627–636. 10.1016/j.jclinepi.2014.12.014 [PubMed: 25704724]

Ayalon L, Hermesh H, & Dagan Y (2002). Case study of circadian rhythm sleep disorder following haloperidol treatment: Reversal by risperidone and melatonin. Chronobiology International, 19(5), 947–959. 10.1081/CBI-120014105 [PubMed: 12405556]

Baker FC, Yuksel D, de Zambotti M (2020). Sex differences in sleep. In Attarian HP, Viola-Saltzman M (Eds.), Sleep disorders in women. Current Clinical Neurology Humana, Cham. 10.1007/978-3-030-40842-8_5

Barabas G, Matthews WS, & Ferrari M (1985). Sleep disorders in Gilles de la Tourette's syndrome. Neurology, 35(9), 1397. 10.1212/WNL.35.9.1397-a [PubMed: 3860750]

Bertisch SM, Herzig SJ, Winkelman JW, & Buettner C (2014). National use of prescription medications for insomnia: NHANES 1999–2010. Sleep, 37(2), 343–349. 10.5665/sleep.3410 [PubMed: 24497662]

Bijlenga D, Vollebregt MA, Kooij JJS, & Arns M (2019). The role of the circadian system in the etiology and pathophysiology of ADHD: Time to redefine ADHD? Attention Deficit and Hyperactivity Disorders, 11(1), 5–19. 10.1007/s12402-018-0271-z [PubMed: 30927228]

Bloch MH, & Leckman JF (2009). Clinical course of Tourette syndrome. Journal of Psychosomatic Research, 67(6), 497–501. 10.1016/j.jpsychores.2009.09.002 [PubMed: 19913654]

Borbély AA, Daan S, Wirz-Justice A, & Deboer T (2016). The two-process model of sleep regulation: A reappraisal. Journal of Sleep Research, 25(2), 131–143. 10.1111/jsr.12371 [PubMed: 26762182]

Brand JPL (1999). "Development, implementation and evaluation of multiple imputation strategies for the statistical analysis of complete data sets." PhD thesis, Rotterdam: Erasmus University.

Brzezinski A, Vangel MG, Wurtman RJ, Norrie G, Zhdanova I, Ben-Shushan A, & Ford I (2005). Effects of exogenous melatonin on sleep: A meta-analysis. Sleep Medicine Reviews, 9(1), 41–50. 10.1016/j.smrv.2004.06.004 [PubMed: 15649737]

Burgess HJ, & Emens JS (2016). Circadian-based therapies for circadian rhythm sleep-wake disorders. Current Sleep Medicine Reports, 2(3), 158–165. 10.1007/s40675-016-0052-1 [PubMed: 27990327]

Buse J, Schoenfeld K, Münchau A, & Roessner V (2013). Neuromodulation in Tourette syndrome: Dopamine and beyond. Neuroscience & Biobehavioral Reviews, 37(6), 1069–1084. 10.1016/j.neubiorev.2012.10.004 [PubMed: 23085211]

Cella D, Lai J-S, Nowinski CJ, Victorson D, Peterman A, Miller D, Bethoux F, Heinemann A, Rubin S, Cavazos JE, Reder AT, Sufit R, Simuni T, Holmes GL, Siderowf A, Wojna V, Bode R, McKinney N, Podrabsky T, … Moy C (2012). Neuro-QOL: Brief measures of health-related quality of life for clinical research in neurology. Neurology, 78(23), 1860–1867. 10.1212/WNL.0b013e318258f744 [PubMed: 22573626]

Champion LM, Fulton WA, & Shady GA (1987). Tourette syndrome and social functioning in a Canadian population. Neuroscience and Biobehavioral Reviews, 12(3–4), 255–257. 10.1016/S0149-7634(88)80054-X

Chong Y, Fryer CD, & Gu Q (2013). Prescription sleep aid use among adults: United States, 2005 – 2010. NCHS Data Brief, (127), 1–8.

Clarke TC, Black LI, Stussman BJ, Barnes PM, & Nahin RL (2015). Trends in the use of complementary health approaches among adults: United States, 2002–2012. National Health Statistics Report, (79), 1–16.

Claudio-Campos K, Stevens D, Koo S-W, Valko A, Bienvenu OJ, Budman CB, Cath DC, Darrow S, Geller D, Goes FS, Grados MA, Greenberg BD, Greenberg E, Hirschtritt ME, Illmann C, Ivankovic F, King RA, Knowles JA, Krasnow J, … for the Tourette Association of America International Consortium for Genetics (TAAICG) and the OCD Collaborative Genetics Association Study (OCGAS). (2021). Is persistent motor or vocal tic disorder a milder form of Tourette syndrome? Movement Disorders, 36(8), 1899–1910. 10.1002/mds.28593 [PubMed: 33942911]

Cohen J (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Academic.

Cohrs S, Rasch T, Altmeyer S, Kinkelbur J, Kostanecka T, Rothenberger A, Ruther E, & Hajak G (2001). Decreased sleep quality and increased sleep related movements in patients with Tourette's syndrome. Journal of Neurology, Neurosurgery & Psychiatry, 70(2), 192–197. 10.1136/jnnp.70.2.192 [PubMed: 11160467]

Coles ME, & Sharkey KM (2011). Compulsion of chronobiology? A case of severe obsessive-compulsive disorders treated with cognitive-behavioral therapy augmented with chronotherapy. Journal of Clinical Sleep Medicine, 7(3), 307–309. 10.5664/JCSM.1080 [PubMed: 21677902]

Coles ME, Schubert J, Stewart E, Sharkey KM, & Deak M (2020). Sleep duration and timing in obsessive-compulsive disorder (OCD): Evidence for circadian phase delay. Sleep Medicine, 72, 111–117. 10.1016/j.sleep.2020.03.021 [PubMed: 32575000]

Conelea CA, Woods DW, Zinner SH, Budman CL, Murphy TK, Scahill L, … Walkup JT (2013). The impact of Tourette Syndrome in adults: Results from the Tourette Syndrome Impact Survey. Community Mental Health Journal, 49(1), 110–120. 10.1007/s10597-011-9465-y [PubMed: 22052430]

Coogan AN, & McGowan NM (2017). A systematic review of circadian function, chronotype and chronotherapy in attention deficit hyperactivity disorder. ADHD Attention Deficit and Hyperactivity Disorders, 9(3), 129–147. 10.1007/s12402-016-0214-5 [PubMed: 28064405]

Cox RC, & Olatunji BO (2019). Circadian rhythms in obsessive-compulsive disorder: Recent findings and recommendations for future research. Current Psychiatry Reports, 21(7), 54. 10.1007/s11920-019-1033-0 [PubMed: 31165330]

Cox RC, & Olatunji BO (2020). Sleep in the anxiety-related disorders: A meta-analysis of subjective and objective research. Sleep Medicine Reviews, 51, 101282. 10.1016/j.smrv.2020.101282 [PubMed: 32109832]

Cox RC, Parmar AM, & Olatunji BO (2019). Sleep in obsessive-compulsive and related disorders: A selective review and synthesis. Current Opinion in Psychology, 34, 23–26. 10.1016/j.copsyc.2019.08.018 [PubMed: 31539831]

Doghramji K, & Jangro WC (2016). Adverse effects of psychotropic medications on sleep. The Psychiatric Clinics of North America, 39(3), 487–502. 10.1016/j.psc.2016.04.009 [PubMed: 27514301]

Drake ME, Hietter SA, Bogner JE, & Andrews JM (1992). Cassette EEG sleep recordings in Gilles de la Tourette syndrome. Clinical Electroencephalography, 23(3), 142–146. 10.1177/155005949202300 30 [PubMed: 1628407]

Drury H, Wilkinson V, Robertson MM, & Channon S (2016). Self-reported emotion regulation in adults with Tourette's syndrome. Psychiatry Research, 245, 157–163. 10.1016/j.psychres.2016.08.026 [PubMed: 27543829]

Duffy JE, Rimmer DW, & Czeisler CA (2001). Association of intrinsic circadian period with morningness-eveningness, usual wake time, and circadian phase. Behavioral Neuroscience, 115(4), 895–899. 10.1037/0735-7044.115.4.895 [PubMed: 11508728]

Enders CK (2017). Multiple imputation as a flexible tool for missing data handling in clinical research. Behaviour Research and Therapy, 98, 4–18. [PubMed: 27890222]

Erenberg G (1985). Sleep disorders in Gilles de la Tourette's syndrome. Neurology, 35(9), 1397. [PubMed: 3860750]

Erland LAE, Saxena PK (2017). Melatonin natural health products and supplements: Presence of serotonin and significant variability of melatonin content. Journal of Clinical Sleep Medicine, 13(2), 275–281. [PubMed: 27855744]

Ferracioli-Oda E, Qawasmi A, & Bloch MH (2013). Meta-analysis: Melatonin for the treatment of primary sleep disorders. PLoS One, 8(5), e63773. 10.1371/journal.pone.0063773 [PubMed: 23691095]

Fischer D, Lombardi DA, Marucci-Wellman H, & Roenneberg T (2017). Chronotypes in the US – Influence of age and sex. PLoS One, 12(6), e0178782 10.1371/journal.pone.0178782 [PubMed: 28636610]

Foa EB, Huppert JD, Leiberg S, Langner R, Kichik R, Hajcak G, & Salkovskis PM (2002). The Obsessive-Compulsive Inventory: Development and validation of a short version. Psychological Assessment, 14(4), 485–496. 10.1037/1040-3590.14.4.485 [PubMed: 12501574]

Freeman D, Sheaves B, Waite F, Harvey AG, & Harrison PJ (2020). Sleep disturbance and psychiatric disorders. Lancet Psychiatry, 7(7), 628–637. 10.1016/S2215-0366(20)30136-X [PubMed: 32563308]

Gao Q, Sheng J, Qin S, & Zhang L (2020). Chronotypes and affective disorders: A clock for mood? Brain Science Advances, 5(3), 145–160. 10.26599/BSA.2019.9050018

Glaze DG, Frost JD, & Jankovic J (1983). Sleep in Gilles de la Tourette's syndrome: Disorder of arousal. Neurology, 33(5), 586–592. 10.1212/WNL.33.5.586 [PubMed: 6573576]

Groth C, Debes NM, Rask CU, Lange T, & Skov L (2017). Course of Tourette syndrome and comorbidities in a large prospective clinical study. Journal of the American Academy of Child and Adolescent Psychiatry, 56(4), 304–312. 10.1016/j.jaac.2017.01.010 [PubMed: 28335874]

Hale L, Troxel W, & Buysse DJ (2020). Sleep Health: An opportunity for public health to address equity. Annual Review of Public Health, 41, 81–99. 10.1146/annurev-publhealth-040119-094412

Hardt J, Herke M, Brian T, & Laubach W (2013). Multiple imputation of missing data: A stimulation study on a binary response. Open Journal of Statistics, 3(5), 370–378. 10.4236/ojs.2013.35043

Hirschtritt ME, Lee PC, Pauls DL, Dion Y, Grados MA, Illmann C, King RA, Sandor P, McMahon WM, Lyon GJ, Cath DC, Kurlan R, Robertson MM, Osiecki L, Scharf JM, Mathews CA, & Tourette Syndrome Association International Consortium for Genetics. (2015). Lifetime prevalence, age of risk, and genetic relationships of comorbid psychiatric disorders in Tourette syndrome. JAMA Psychiatry, 72(4), 325–333. 10.1001/jamapsychiatry.2014.2650 [PubMed: 25671412]

Horne JA, & Östberg O (1977). Individual differences in human circadian rhythms. Biological Psychiatry, 5(3), 179–190. 10.1016/0301-0511(77)90001-1

Ivarsson T, & Skarphedinsson G (2015). Sleep problems and cognitive behavior therapy in pediatric obsessive-compulsive disorder have bidirectional effects. Journal of Anxiety Disorders, 30, 28–33. 10.1016/j.janxdis.2014.12.009 [PubMed: 25591044]

Jalenques I, Galland F, Malet L, Morand D, Legrand G, Auclair C, Hartmann A, Derost P, & Durif F (2012). Quality of life in adults with Gilles de la Tourette syndrome. BMC Psychiatry, 12, 109. 10.1186/1471-244X-12-109 [PubMed: 22888766]

Jankovic J, Gelineau-Kattner R, & Davidson A (2010). Tourette's syndrome in adults. Movement Disorders, 25(13), 2171–2175. 10.1002/mds.23199 [PubMed: 20690167]

Jankovic J, & Rohaidy H (1987). Motor, behavioral and pharmacologic findings in Tourette's syndrome. Canadian Journal of Neurological Sciences, 14(S3), 541. 10.1017/S0317167100038087

Ji X, Wu M, & Zhang X (2016). Dopamine level in the striatum exhibits circadian rhythms in the rat model of Tourette syndrome. International Journal of Clinical Experimental Medicine, 9(6), 9015–9020.

Jiménez-Jiménez FJ, Alonso-Navarro H, García-Martín E, & Agúndez JAG (2020). Sleep disorders in Tourette syndrome. Sleep Medicine Reviews, 53, 101335. 10.1016/j.smrv.2020.101335 [PubMed: 32554211]

Johnson EO, Roehrs T, Roth T, & Brelsau N (1998). Epidemiology of alcohol and medication as aids to sleep in early adulthood. Sleep, 21(2), 178–186. 10.1093/sleep/21.2.178 [PubMed: 9542801]

Kamphuis J, & Lancel M (2015). Chapter 12 – The interrelations between sleep, anger, and loss of aggression control. In Babson KA & Feldner MT (Eds.), Sleep and Affect: Assessment, Theory, and Clinical Implications (pp. 247–271). Academic Press. 10.1016/B978-0-12-417188-6.00012-8

Kantermann T, Sung H, & Burgess HJ (2015). Comparing the Morningness-Eveningness Questionnaire and Munich Chronotype Questionnaire to the dim light melatonin onset. Journal of Biological Rhythms, 30(5), 449–453. 10.1177/0748730415597520 [PubMed: 26243627]

Khubchandani J, Brey R, Kotecki J, Kleinfelder J, & Anderson J (2016). The psychometric properties of PHQ-4 depression and anxiety screening scale among college students. Archives of Psychiatric Nursing, 30(4), 457–462. 10.1016/j.apnu.2016.01.014 [PubMed: 27455918]

Kim SM, Park JM, & Seo H-J (2016). Effects of mindfulness-based stress reduction for adults with sleep disturbance: A protocol for an update of a systematic review and meta-analysis. Systematic Reviews, 5, 51. 10.1186/s13643-016-0228-2 [PubMed: 27039290]

Kirov R, Becker A, & Rothenberger A (2014). Sleep in Tourette syndrome. Current Developmental Disorders Reports, 1, 252–259. 10.1007/s40474-014-0028-0

Kirov R, Kinkelbur J, Banaschewski T, & Rothenberger A (2007). Sleep patterns in children with attention-deficit/hyperactivity disorder, tic disorders, and comorbidity. Journal of Child Psychology and Psychiatry, 48(6), 561–570. 10.1111/j.1469-7610.2007.01729.x [PubMed: 17537072]

Kivelä L, Papadopoulos MR, & Antypa N (2018). Chronotype and psychiatric disorders. Current Sleep Medicine Reports, 4, 94–103. 10.1007/s40675-018-0113-8 [PubMed: 29888167]

Kleinke K (2017). Multiple imputation under violated distributional assumptions: A systematic evaluation of the assumed robustness of predictive mean matching. Journal of Educational and Behavioral Statistics, 42(4), 371–404. 10.3102/1076998616687084

Kostanecka-Endress T, Banaschewski T, Kinkelbur J, Wüllner I, Lichtblau S, Cohrs S, Ruther E, Woerner W, Hajak G, & Rothenberger A (2003). Disturbed sleep in children with Tourette syndrome: A polysomnographic study. Journal of Psychosomatic Research, 55(1), 23–29. 10.1016/S0022-3999(02)00602-5 [PubMed: 12842228]

Kroenke K, Spitzer RL, Williams JB, & Lowe B (2009). An ultra-brief screening scale for anxiety and depression: The PHQ-4. Psychosomatics, 50(6), 613–621. 10.1016/S0033-3182(09)70864-3 [PubMed: 19996233]

Kuula L, Pesonen A-K, Heinonen K, Kajantie E, Eriksson JG, Andersson S, Lano A, Lahti J, Wolke D, & Räikkönen K (2017). Naturally occurring circadian rhythm and sleep duration are related to executive functions in early adulthood. Journal of Sleep Research, 27(1), 113–119. 10.1111/jsr.12581 [PubMed: 28726307]

Leckman JF (2003). Phenomenology of tics and natural history of tic disorders. Brain and Development, 25(S1), S24–S28. 10.1016/S0387-7604(03)90004-0 [PubMed: 14980368]

Leckman JF, King RA, & Bloch MH (2014). Clinical features of Tourette syndrome and tic disorders. Journal of Obsessive-Compulsive and Related Disorders, 3(4), 372–379. 10.1016/j.jocrd.2014.03.004 [PubMed: 30197854]

Leon AC, Shear MK, Portera L, & Klerman GL (1992). Assessing impairment in patients with panic disorder: The Sheehan Disability Scale. Social Psychiatry and Psychiatric Epidemiology, 27(2), 78–82. 10.1007/BF00788510 [PubMed: 1594977]

Lespérance P, Djerroud N, Anzaldua AD, Rouleau GA, Chouinard S, & Richer F (2004). Restless legs in Tourette syndrome. Movement Disorders, 19, 1084–1087. 10.1002/mds.20100 [PubMed: 15372602]

Levine JLS, Szejko N, & Bloch MH (2019). Meta-analysis: Adulthood prevalence of Tourette syndrome. Progress in Neuro-Psychopharmacology and Biological Psychiatry, 95, 109675. 10.1016/j.pnpbp.2019.109675 [PubMed: 31220521]

Li C (2013). Little's test of missing completely at random. The Stata Journal, 13(4), 795–809. 10.1177/1536867X1301300407

Li J, Vitiello M, & Gooneratne N (2019). Sleep in normal aging. Sleep Medicine Clinics, 13(1), 1–11. 10.1016/j.jsmc.2017.09.001

Mallampalli MP, & Carter CL (2014). Exploring sex and gender differences in sleep health: A society for women's health research report. Journal of Women's Health, 23(7), 553–562. 10.1089/jwh.2014.4816

Maluly M, Andersen ML, Dal-Fabbro C, Gabruio S, Bittencourt L, de Siqueira JTT, & Tufik S (2013). Polysomnographic study of the prevalence of sleep bruxism in a population sample. Journal of Dental Research, 92, S92–S103. 10.1177/0022034513484328

Matheson E, & Hainer BL (2017). Insomnia: Pharmacologic therapy. American Family Physician, 96(1), 29–35. [PubMed: 28671376]

McGuire JF, Arnold E, Park JM, Nadeau JM, Lewin AB, Murphy TK, & Storch EA (2015). Living with tics: Reduced impairment and improved quality of life for youth with chronic tic disorders. Psychiatry Research, 225(3), 571–579. 10.1016/j.psychres.2014.11.045 [PubMed: 25500348]

Mela CF, & Kopalle PK (2002). The impact of collinearity on regression analysis: The asymetric effect of negative and positive correlations. Applied Economics, 34, 667–677. 10.1080/00036840110058482

Mendoza J, & Challett E (2014). Circadian insights into dopamine mechanisms. Neuroscience, 282(12), 230–242 10.1016/j.neuroscience.2014.07.081 [PubMed: 25281877]

Modafferi S, Stornelli M, Chiarotti F, Cardona F, & Bruni O (2016). Sleep, anxiety and psychiatric symptoms in children with Tourette syndrome and tic disorders. European Journal of Paediatric Neurology, 20(5), 292–703. 10.1016/j.ejpn.2016.05.003

Morand-Beaulieu S, Grot S, Lavoie J, Leclerc JB, Luck D, & Lavoie ME (2017). The puzzling question of inhibitory control in Tourette syndrome: A meta-analysis. Neuroscience and Biobehavioral Reviews, 80, 240–242. 10.1016/j.neubiorev.2017.05.006 [PubMed: 28502600]

Muazzam A, & Ahmad A (2017). Predictors of sleep disturbances among college students: Interplay of media exposure and health related quality of life. Pakistan Journal of Psychological Research, 32(2), 393–406.

Müller-Vahl KR, Kayser L, Pisarenko A, Haas M, Psathakis N, Palm, & Jakubovski E (2020). The Rage Attack Questionnaire-Revised (RAQ-R): Assessing rage attacks in adults with Tourette syndrome. Frontiers in Psychiatry, 10, 956. 10.3389/fpsyt.2019.00956 [PubMed: 32063867]

Murphy M, & Peterson MJ (2015). Sleep disturbances in depression. Sleep Medicine Clinics, 10(1), 17–23. 10.1016/j.jsmc.2014.11.009 [PubMed: 26055669]

Naguy A (2016). Clonidine use in psychiatry: Panacea or panache? Pharmacology, 98, 87–92. 10.1159/000446441 [PubMed: 27161101]

Nordahl H, Havnen A, Hansen B, Ost L-G, & Kvale G (2017). Sleep disturbances in treatment-seeking OCD-patients: Changes after concentrated exposure treatment. Scandinavian Journal of Psychology, 59(2), 186–191. 10.1111/sjop.12417 [PubMed: 29244201]

Nota JA, Sharkey KM, & Coles ME (2015). Sleep, arousal, and circadian rhythms in adults with obsessive-compulsive disorder: A meta-analysis. Neuroscience & Biobehavioral Reviews, 51, 100–107. 10.1016/j.neubiorev.2015.01.002 [PubMed: 25603315]

Oral E, Ozcan H, Gulec M, Selvi Y, & Aydin A (2011). Psychotropic medications affecting biological rhythm. Journal of Mood Disorders, 1(4), 169–177. 10.5455/jmood.20111220034620

Partonen T (2015). Chronotype and health outcomes. Current Sleep Medicine Reports, 1, 205–211. 10.1007/s40675-015-0022-z

Pringsheim T, Nosratmirshekarlou E, Doja A, & Martino D (2021). Physical activity, sleep and neuropsychiatric symptom severity in children with Tourette syndrome. European Child and Adolescent Psychiatry, 30(5), 711–719. 10.1007/s00787-020-01552-1 [PubMed: 32372272]

QuickStats. (2019). Percentage of adults aged 18 years who took medication to help fall or stay asleep four or more times in the past week, by sex and age group – National Health Interview Survey, United States, 2017–2018. Morbidity Mortality Weekly Report, 68(49), 1150. 10.15585/mmwr.mm6849a5 [PubMed: 31830011]

Randler C, & Engelke J (2019). Gender differences in chronotype diminish with age: A meta-analysis based on morningness/chronotype questionnaires. Chronobiology International, 36(7), 888–905. 10.1080/07420528.2019.1585867 [PubMed: 31070061]

Reese HE, Vallejo Z, Rasmussen J, Crowe K Rosenfield E, & Wilhlem S (2015). Mindfulness-based stress reduction for Tourette syndrome and chronic tic disorder: A pilot study. Journal of Psychosomatic Research, 78(3), 293–298. 10.1016/j.jpsychores.2014.08.001 [PubMed: 25149879]

Ricketts EJ, Burgess HJ, Montalbano GE, Coles ME, McGuire JF, Thamrin H, Colwell CS (2022). Morning light therapy in adults with Tourette's disorder. Journal of Neurology, 269(1), 399–410. 10.1007/s00415-021-10645-z [PubMed: 34120225]

Riha RL (2018). The use and misuse of exogenous melatonin in the treatment of sleep disorders. Current Opinion in Pulmonary Sleep Medicine, 24(6), 543–548. 10.1097/MCP.0000000000000522

Rivière J-B, Xiong L, Levchenko A, St-Onge J, Gaspar C, Dion Y, Lespèrance P, Tellier G, Richer F, Chouinard S, Rouleau GA, & Montreal Tourette Study Group. (2009). Association of intronic variants of the $BTBD_9$ gene with Tourette syndrome. Archives of Neurology, 66(10), 1267–1272. 10.1001/archneurol.2009.213 [PubMed: 19822783]

Robertson MM, Eapen V, Singer HS, Martino D, Scharf JM, Paschou P, Roessner V, Woods DW, Hariz M, Mathews CA, Črnčec R, & Leckman JF (2017). Gilles de la Tourette syndrome. Nature Reviews Disease Primers, 3, 16097. 10.1097/MCP.0000000000000522

Roenneberg T, Kuehnle T, Pramstaller PP, Ricken J, Havel M, Guth A, & Merrow M (2004). A marker for the end of adolescence. Current Biology, 14(24), R1038–R1039. 10.1016/j.cub.2004.11.039 [PubMed: 15620633]

Roenneberg T (2015). Having trouble typing? What on earth is chronotype? Journal of Biological Rhythms, 30(6), 487–491. 10.1177/0748730415603835 [PubMed: 26446872]

Romano A, Cundari RA, Bruni O, & Cardona F (2004). Tic disorders and arousal dysfunction: Clinical evaluation of 49 children and adolescents. Minerva Pediatrica, 56(3), 327–334. [PubMed: 15252381]

Rombach I, Gray AM, Jenkinson C, Murray DW, & Rivero-Arias O (2018). Multiple imputation for patient reported outcome measures in randomised controlled trials: advantages and disadvantages of imputing at the item, subscale, or composite score level. BMC Medical Research Methodology, 18(1), 87. 10.1186/s12874-018-0542-6 [PubMed: 30153796]

Rzepka-Migut B, & Paprocka J (2020). Efficacy and safety of melatonin treatment in children with autism spectrum disorder and attention-deficit/hyperactivity disorder – A review of the literature. Brain Sciences, 10(4), 219. http://dx.doi.org/0.3390/brainsci10040219

Sambrani T, Jakubovski E, & Müller-Vahl KR (2016). New insights into clinical characteristics of Gilles de la Tourette syndrome: Findings in 1032 patients from a single German center. Frontiers in Neuroscience, 10, 415. 10.3389/fnins.2016.00415 [PubMed: 27672357]

Schlarb AA, Sopp R, Ambiel D, & Grunwald J (2014). Chronotype-related differences in childhood and adolescent aggression and antisocial behavior – A review of the literature. Chronobiology International, 31(1), 1–16. 10.3109/07420528.2013.829846 [PubMed: 24147657]

Scott AJ, Webb TL, Martyn-St. James M, Rowse G, & Weich S (2021). Improving sleep quality leads to better mental health: A meta-analysis of randomised controlled trials. Sleep Medicine Reviews, 60, 101556. 10.1016/j.smrv.2021.101556 [PubMed: 34607184]

Sheehan DV (1983). The Anxiety Disease. New York: Charles Scribner and Sons.

Snitselaar MA, Smits MG, van der Heijden KB, & Spijker J (2017). Sleep and circadian rhythmicity in adult ADHD and the effect of stimulants. Journal of Attention Disorders, 21(1), 14–26. 10.1177/108705471347966 [PubMed: 23509113]

Stephens RJ, Chung S, Dragana J, Guerra R, Stephens B, Sandor P, & Shapiro S (2013). Relationship between polysomnographic sleep architecture and behavior in medication-free children with TS, ADHD, TS and ADHD, and controls. Journal of Developmental and Behavioral Pediatrics, 34(9), 688–696. 10.1097/DBP.0000000000000012 [PubMed: 24247912]

Storch EA, Milsom V, Lack CW, Pence SL, Geffken GR, Jacob ML, Goodman WK, & Murphy TK (2009). Sleep-related problems in youth with Tourette's syndrome and chronic tic disorder. Child and Adolescent Mental Health, 14(2), 97–103. 10.1111/j.1475-3588.2008.00497.x

Tanner J, Zeffiro T, Wyss D, Perron N, Rufer M, & Mueller-Pfeiffer C (2019). Psychiatric symptom profile predict functional impairment. Frontiers in Psychiatry, 10, 37. 10.3389/fpsyt.2019.00037 [PubMed: 30853916]

Taylor BJ, & Hasler BP (2018). Chronotype and mental health: Recent advances. Current Psychiatry Reports, 20, 59. 10.1007/s11920-018-0925-8 [PubMed: 30039327]

Ustun B, Adler LA, Rudin C, Faraone SV, Spencer TJ, Berglund P, Gruber MJ, & Kessler RC (2017). The World Health Organization Adult Attention-Deficit/Hyperactivity Disorder Self-Report Screening Scale for DSM-5. JAMA Psychiatry, 74(5), 520–526. 10.1001/jamapsychiatry.2017.0298 [PubMed: 28384801]

Van Buuren S (2018). Flexible imputation of missing data, 2nd edition. Chapman and Hall/CRC.

Vandekerckhove M, & Wang Y-L (2017). Emotion, emotion regulation and sleep: An intimate relationship. Neuroscience, 5(1), 1–17. 10.3934/Neuroscience.2018.1.1

Wand RR, Matazow GA, Shady P, Furer D, & Staley D (1993). Tourette syndrome: Associated symptoms and most disabling features. Neuroscience and Biobehavioral Reviews, 17(3), 271–275. 10.1016/s0149-7634(05)80010-7 [PubMed: 8272283]

Watts A, & Norbury R (2017). Reduced effective emotion regulation in night owls. Journal of Biological Rhythms, 32(4), 369–375. 10.1177/0748730417709111 [PubMed: 28627300]

Woods DW, Piacentini J, Change SW, Deckersbach T Ginsburg GS, Peterson AL, Scahill LD, Walkup JT, & Wilhelm S (2008). Managing Tourette syndrome. A behavioral intervention for children and adults. Therapist Guide Oxford University Press. 10.1093/med:psych/9780195341287.001.0001

Yu L, Buysse DJ, Germain A, Moul DE, Stover A, Dodds NE, Johnston KL, & Pilkonis PA (2012). Development of short forms from the PROMIS™ Sleep Disturbance and Sleep-Related Impairment item banks. Behavioral Sleep Medicine, 10(1), 6–24. 10.1080/15402002.2012.636266

Zavada A, Gordijn MCM, Beersma DGM, Daan S, & Roenneberg T (2005). Comparison of the Munich Chronotype Questionnaire with the Horne-Östberg's Morningness-Eveningness score. Chronobiology International, 22(2), 267–278. 10.1081/cbi-200053536 [PubMed: 16021843]

Table 1

Sample demographic characteristics

Characteristic	n	%
Sex		
Male	53	44.2%
Female	67	55.8%
Race		
White	111	91.0%
Black/African-American	2	1.6%
American Indian or Alaskan Native	3	2.5%
Biracial	3	2.5%
Other	3	2.5%
Ethnicity		
Hispanic	10	8.3%
Non-Hispanic	111	91.7%
Highest Educational Level		
Some high school or less	5	4.1%
High school diploma or equivalent	26	21.3%
Technical/trade school or some college	21	17.2%
Junior/community college	8	6.6%
College graduate or equivalent	41	33.6%
Postgraduate/professional degree	21	17.2%
Employment	81	66.4%
Full time	57	46.7%
Part-time	24	19.7%
Not employed	38	31.1%
Retired	3	2.4%
Marital status		
Married	30	24.4%
Divorced	7	5.7%
Separated	3	2.4%
Single	78	63.4%
Other	5	4.1%
Household income		
$0 – $29,999	34	28.3%
$30,000 – $59,999	32	26.7%
$60,000 – $89,999	20	16.7%
$90,000 – $119,999	7	5.8%
$120,000 – $149,999	10	8.3%
$150,000 – $170,000	3	2.5%
$180,000 – $209,999	2	1.7%
$210,000 or more	12	10.0%

Note. Data are presented for available cases. Valid percentages are reported

Table 2

Sample clinical characteristics

Characteristic	n	%	
Medication			
Lifetime use of tic medication	85	70.2%	
Current use of tic medication	56	46.3%	
Current prescribed or over-the-counter sleep medication	48	40.0%	
Ambien (zolpidem)	2	1.7%	
Belsomra (suvorexant)	0	0.0%	
Desyrel (trazodone)	3	2.5%	
Halcion (triazolam)	1	0.9%	
Lunesta (eszopiclone)	3	2.6%	
Restoril (temazepam)	0	0.0%	
Rozerem (ramelteon)	0	0.0%	
Sonata (zaleplon)	0	0.0%	
Silenor (doxepine)	0	0.0%	
Xanax (alprazolam)	4	3.5%	
Benadryl, Unisom sleep gels, etc. (diphenhydramine)	13	11.1%	
Unisom sleep tabs (doxylamine succinate)	3	2.6%	
Melatonin	32	27.1%	
Valerian	5	4.3%	
Other	11	9.5%	
Tics Before and During Sleep in Past Month			
Tics made it hard to fall asleep	69	56.1%	
Tics are displayed during sleep	26	21.1%	
Sleep, Chronotype, and Clinical Symptoms M (SD)	**M**	**SD**	**Minimum and Maximum Score[a]**
Sleep disturbance	55.92	7.60	28.9–76.50
Chronotype	45.39	10.70	16–86
Tic severity	57.33	32.38	0–216
Motor	38.12	19.05	0–112
Vocal	19.08	17.40	0–104
Impairment	10.83	7.21	0–30
ADHD	13.79	5.14	0–24
Obsessive-compulsive symptoms	22.54	12.77	0–72
Anxiety	3.51	1.87	0–6
Depression	2.50	2.07	0–6
Emotional and behavioral dyscontrol	53.61	8.16	32.2–82.60

Note. Frequencies and means are presented for available cases. Valid percentages are reported. The minimum and maximum scores for each questionnaire are reported for the purposes of interpretation of clinical severity of the sample. These numbers do not refer to the minimum and maximum of the sample data. Sleep Disturbance = Patient Reported Outcomes Measurement Information System-Sleep Disturbance, Short Form. Chronotype = Morningness-Eveningness Questionnaire; Tic Severity = Adult Tic Questionnaire; Impairment = The Sheehan Disability Scale; ADHD = The ADHD Self-Report Screening Scale for DSM-5; Obsessive-compulsive symptoms = The Obsessive-Compulsive Inventory-Revised; Anxiety and Depression = Patient Health Questionnaire-4; Emotional and Behavioral Dyscontrol = NeuroQol Emotional and Behavioral Dyscontrol, Short Form.

J Clin Psychol. Author manuscript; available in PMC 2023 July 01.

Table 3

Lifetime Co-occurring Psychiatric and Sleep Disorders

Lifetime Psychiatric Disorders	n	%	Lifetime Sleep Disorders	n	%
≥ 1 co-occurring psychiatric disorder	118	98.3%	≥ 1 co-occurring sleep disorder	76	63.3%
Attention-deficit/hyperactivity disorder (ADHD or ADD)	58	48.3%	Insomnia	29	24.0%
Obsessive-compulsive disorder	49	41.2%	Hypersomnia	4	3.4%
Trichotillomania (hair-pulling disorder)	7	5.8%	Bruxism (teeth grinding)	35	29.2%
Excoriation (skin-picking disorder)	10	8.3%	Obstructive sleep apnea	12	10.1%
Body dysmorphic disorder	9	7.4%	Delayed sleep-wake phase disorder	4	3.4%
Hoarding disorder	2	1.7%	Advanced sleep-wake phase disorder	0	0.0%
Generalized anxiety disorder	61	50.4%	Shift work sleep disorder	1	0.8%
Social Phobia (social anxiety disorder)	32	26.9%	Narcolepsy	1	0.8%
Panic disorder	17	14.2%	Sleep walking	12	10.1%
Agoraphobia	4	3.3%	Nocturnal enuresis	5	4.2%
Specific phobia	8	6.7%	Night terror	10	8.4%
Major depressive disorder	49	40.5%	Nightmares	21	17.5%
Bipolar Disorder	6	5.1%	Restless legs syndrome	15	12.5%
Posttraumatic stress disorder	19	15.8%	Periodic limb movement disorder	1	0.8%
Anorexia nervosa	5	4.2%	Rapid eye movement behavior disorder	0	0.0%
Bulimia nervosa	2	1.7%	Sleep paralysis	4	3.3%
Binge eating disorder	4	3.4%			
Alcohol use disorder	8	6.7%			
Drug use disorder	9	7.6%			

Note. Frequencies are presented for available cases. Valid percentages are reported.

Table 4

Pooled Pearson Bivariate Correlations between Sleep Disturbance, Chronotype, and Clinical Symptoms in Persistent Tic Disorders Sample, and Tourette's Disorder Subsample

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11	*M*	*SD*
1. Sleep disturbance	55.94	7.36	—	.06	.19	.11	.19	.31**	.10	.32**	.16	.14	.33**	55.98	7.35
2. Chronotype	45.70	10.45	.02	—	−.11	−.18	−.18	−.03	−.15	.08	.12	−.02	.03	45.52	10.59
3. Motor tic severity	37.89	17.54	.17	−.19	—	.34**	.84**	.28**	.19*	.30**	.26*	.14	.07	38.55	17.82
4. Vocal tic severity	19.05	16.37	.11	−.23*	.34**	—	.80**	.49**	.26*	.15	.16	.28*	.28**	18.69	16.42
5. Total tic severity	56.95	27.91	.17	−.25*	.83**	.80*	—	.46**	.27**	.28*	.26*	.25*	.21*	57.25	28.04
6. Impairment	10.47	7.16	.31*	−.05	.26*	.52**	.47**	—	.34**	.42**	.37**	.32**	.45**	10.69	7.08
7. ADHD	13.70	5.19	.10	−.13	.22*	.28*	.30*	.40**	—	.42**	.22*	.36**	.37**	13.75	5.06
8. Obsessive-compulsive symptoms	21.29	12.37	.30**	.06	.26*	.17	.27*	.43**	.42**	—	.46**	.37**	.45**	21.89	12.31
9. Anxiety	3.47	1.90	.15	.11	.26*	.17	.26*	.37	.22	.45**	—	.50**	.33**	3.49	1.86
10. Depression	2.52	2.03	.13	−.04	.13	.27*	.24*	.32**	.37**	.39**	.51**	—	.41**	2.52	2.03
11. Emotional and behavioral dyscontrol	53.41	7.97	.30**	−.01	.06	.27*	.19	.48**	.39**	.45**	.35**	.41**	—	53.33	8.08

Note. Pearson bivariate correlations were conducted on imputed data. *M* = mean; *SD* = standard deviation; White = bivariate correlations for adults with PTDs (n = 125); Grey = bivariate correlations for TD subsample (n = 115).

* $p < .05$,

** $p < .01$.

Table 5

Pooled Regression Estimates for Clinical Predictors of Sleep Disturbance in Persistent Tic Disorders Sample, and Tourette's Disorder Subsample

Model	Predictor	*B*	SE	*β*	*t*	*p*	VIF	Adj. R^2	Cohen's f^2
Full Sample									
1	Full Model							.18	.22
	Constant	41.92	5.45		7.70	<.001			
	Age	0.11	0.06	.17	1.83	.07	1.14		
	Sex	−1.68	1.35	−.11	−1.24	.22	1.11		
	Tic Severity	0.02	0.03	.09	0.74	.46	1.36		
	Impairment	0.18	0.17	.17	1.10	.28	1.70		
	ADHD	−0.17	0.17	−.12	−1.02	.31	1.43		
	Obsessive-compulsive symptoms	0.14	0.08	.24	1.91	.06	1.68		
	Anxiety	−0.25	0.49	−.06	−0.51	.61	1.63		
	Depression	−0.11	0.49	−.03	−.022	.82	1.75		
	Emotional and behavioral dyscontrol	0.17	0.12	.18	1.44	.16	1.66		
2	Final Model							.13	.15
	Constant	48.32	2.24		21.53	<.001			
	Age	0.12	0.06	.20	2.06	.04	1.01		
	Obsessive-compulsive symptoms	0.18	0.06	.31	3.07	.003	1.01		
Model	**Predictor**	***B***	**SE**	***β***	***t***	***p***	**VIF**	**Adj. R^2**	**Cohen's f^2**
Tourette's Disorder Subsample									
1	Full Model							.15	.18
	Constant	41.66	6.15		6.77	<.001			
	Age	0.12	0.07	.18	1.82	.07	1.14		
	Sex	−1.63	1.46	−.11	−1.11	.27	1.15		
	Tic Severity	0.02	0.03	.08	0.68	.50	1.42		
	Impairment	0.19	0.18	.19	1.05	.31	1.78		
	ADHD	−0.18	0.18	−.12	−0.99	.33	1.50		
	Obsessive-compulsive symptoms	0.14	0.08	.23	1.68	.10	1.70		
	Anxiety	−0.35	0.51	−.09	−0.70	.49	1.67		
	Depression	−0.05	0.53	−.01	−0.09	.93	1.79		
	Emotional and behavioral dyscontrol	0.17	0.13	.18	1.34	.19	1.69		
2	Final Model							.12	.14
	Constant	48.66	2.37		20.56	<.001			
	Age	0.13	0.06	.20	2.03	.04	1.00		
	Impairment	0.33	0.12	.32	2.83	.01	1.00		

Note. Regression was conducted on imputed data. *B* = unstandardized beta; SE = standard error; *β* = standardized beta; VIF = variance inflation factor; Adj. = adjusted.

Table 6

Pooled Regression Estimates for Clinical Predictors of Chronotype in Persistent Tic Disorders Sample, and Tourette's Disorder Subsample

Model	Predictor	*B*	SE	*β*	*t*	*p*	VIF	Adj. R^2	Cohen's f^2
Persistent Tic Disorders									
1	Full Model							.12	.14
	Constant	44.67	8.95		4.99	<.001			
	Age	0.21	0.11	.23	1.93	.06	1.14		
	Sex	−2.10	2.05	−.10	−1.02	.31	1.11		
	Tic Severity	−0.07	0.04	−.18	−1.56	.12	1.36		
	Impairment	0.04	0.23	.03	0.18	.86	1.70		
	ADHD	−0.36	0.27	−.17	−1.35	.18	1.43		
	Obsessive-compulsive symptoms	0.11	0.13	.13	0.89	.38	1.68		
	Anxiety	0.77	0.82	.14	0.94	.35	1.63		
	Depression	−0.10	0.67	−.02	−0.15	.88	1.75		
	Emotional and behavioral dyscontrol	−0.01	0.20	−.01	−0.08	.93	1.66		
2	Final Model							.07	.08
	Constant	38.19	3.42		11.17	<.001			
	Age	0.24	0.11	.27	2.21	.03	1.00		
Model	**Predictor**	***B***	**SE**	***β***	***t***	***p***	**VIF**	**Adj. R^2**	**Cohen's *f*2**
Tourette's Disorder Subsample									
1	Full Model							.14	.16
	Constant	45.60	9.77		4.67	<.001			
	Age	0.24	0.12	.26	2.10	.04	1.14		
	Sex	−1.30	2.12	−.06	−0.62	.54	1.15		
	Tic Severity	−0.10	0.05	−.26	−2.17	.03	1.42		
	Impairment	0.09	0.23	.06	0.37	.71	1.78		
	ADHD	−0.21	0.28	−.10	−0.76	.45	1.50		
	Obsessive-compulsive symptoms	0.09	0.13	.11	0.70	.49	1.70		
	Anxiety	0.73	0.85	.14	0.86	.39	1.67		
	Depression	−0.05	0.68	−.01	−0.07	.94	1.79		
	Emotional and behavioral dyscontrol	−0.06	0.21	−.05	−0.30	.77	1.69		
2	Final Model							.	
	Constant	42.93	4.33		9.93	<.001		.12	.14
	Age	0.25	0.11	.27	2.25	.03	1.01		
	Tic severity	−0.09	0.04	−.23	−2.36	.02	1.01		

Note. Regression was conducted on imputed data. *B* = unstandardized beta; SE = standard error; *β* = standardized beta; VIF = variance inflation factor; Adj. = adjusted.